NASA Safety

Cultural Improvements

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Outline

- Culture
- Organizational Accident Models
  - High Reliability
  - Normal Accidents
- Psychology of Decisions
- Preventing The Next Accident
- Bibliography

Challenge

- **Highly advanced technology**
  - **Tremendous energy required to accelerate 100 tons to orbital velocity**
  - **Must intellectually manage this advanced technology**
    - **System is large, complex, unpredictable, cannot test everything, cannot foresee all possible environments**

Culture

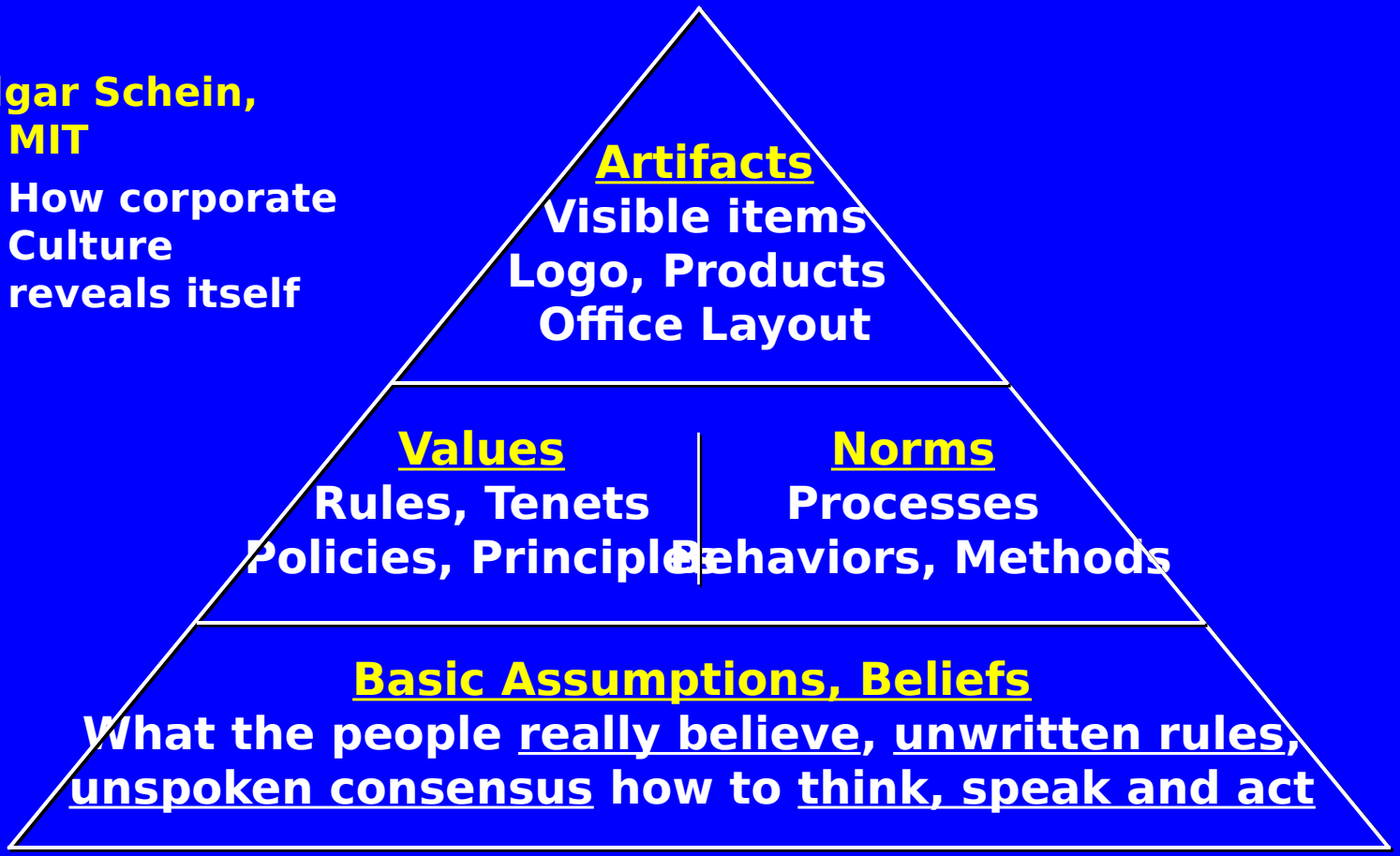
- **Psychologist's Definition**
  - **Culture is the shared values, beliefs and norms for behavior in the organization.**
  - **Defined by mostly unspoken and sometimes unconscious consensus about how people should think, speak and act.**

- **Changing the culture is very simple; but it's not very easy.**

Corporate Culture

Edgar Schein, MIT

How corporate Culture reveals itself



Culture

- **Safety Culture is measured by the alignment of Values, Beliefs, and Behaviors.** ★
  - ***Values*** **are basic principles or tenets preserved by the policies, rules and methods specified by leaders to guide the organization.**
  - ***Beliefs*** **are what the members of the organization really think.**
  - ***Behaviors*** **are what the workers really do in practice. They are how people talk in meetings, the quality of questions asked, how people elevate or resolve issues, and the relationships that different organizations and individual people have when working with each other.**

CULTURAL DNA
Tacit Assumptions

PEOPLE/BELONGING

Sense of Community

- Don't rock the boat
- Don't upset the customer
- Ignore soft skills
- Avoid decision-making (on people issues)
- Lack of unity
- Lack of facilities
- Lack of respect for Safety/Rel/QA
- Lack of HR

STABILITY/STRUCTURE

Materials, Processes, Procedures

- Follow Procedures
- Play the politics
- Hqs has the power
- Don't question authority
- Program Office rules
- MOD/Engin. have power
- Don't jeopardize award fee

RESULTS/MASTERY

Production

- Technical competence
- Get it done at any cost
- Meet the schedule
- Problem solvers
- Self-promoters
- Never say "We can't"

FREEDOM/LEARNING

Flexibility/Openness

- Don't go around chain of command
- Never blind-side your boss
- Don't dissent
- Afraid to ask for help
- Never admit "I don't know"
- Lack of training
- Lack of Devil's Advocate
- Lack of experience

Cultural Change

- **MANAGEMENT**
  - **Acknowledge the need to change**
    - **Master skills of Emotional Intelligence**
    - **Improve continuously**
  - **Leaders must Create Conditions for Cultural Transformation**
    - **Principles: Respect, Candor, Trust, Mindfulness**
    - **Incentives: Goals, Encouragement, Reinforcement, Rewards**
  - **Lead, then Trust**

Cultural Change

- **WORKFORCE**
  - **If Leaders create conditions, Workforce can change Beliefs and Behaviors**

    (More Rules, Policies, Procedures won't work to change behaviors)

    1. **Continue to be technically outstanding**
    2. **Preserve values, don't compromise**
    3. **Reinforce positive behaviors**
    4. **Cope, when required**
    5. **Be ready for advancement**

Theoretical Models

- **A. High Reliability Organizations (Reason, Weick & Sutcliffe, many others)**
  - **Accidents can be prevented**
  - **Must have talented people, great organization**
- **B. Normal Accidents (Charles Perrow)**
  - **Systems are so complex and intertwined that accidents are inevitable**

- **We must anticipate both theories**

A. High Reliability Organizations

- 1. Leadership Commitment – Safety Priority, top to bottom, in the face of other goals!
- 2. Organizational Redundancy – Organizational and Systems redundancy allow errors and malfunctions to be trapped
- 3. Decentralized Capability – Enhance safety by allowing key decisions at all levels, defer to experts; quick response, greater flexibility, absorb mistakes, contain damage, prevent major accidents
- 4. Problem Reporting – Horizontal and vertical, accurate, timely

A. High Reliability Organizations

- **5. Training – Workers keep their skills sharp with practice and emergency drills**
- **6. Learning – Premium on learning lessons from trials and errors; continual monitoring, analysis, feedback; controlled simulations, extensive testing**
- **7. Fairness – Decisions, personnel issues**
- **8. Foresight – Search for Vulnerabilities; requires knowledge of system, vast experience, non-linear thinking**

B. Normal Accidents

- **1. Tight Coupling**
  - **Failures escalate rapidly out of control**
  - **Use Centralization (to defer accident)**
    - **Rapid response, Standard Oper. Procedure**
- **2. Interactive Complexity**
  - **Bizarre, unanticipated failures**
  - **Use Decentralization (to defer accident)**
    - **Flexible, Intuitive Thinking**

B. Normal Accidents

- **Naval Aircraft Carrier operations have both Coupling and Complexity**
  - **Centralized: Continuous Training**
  - **Decentralized: Intense Socialization, with strong "Culture of Responsibility"**
  - **Results in Coordinated Decentralized action to defer accidents**

Theoretical Models

- **A. High Reliability Organizations**
  - **Catastrophic Accidents can be prevented ~99% of the time**
- **B. Normal Accidents**
  - **Catastrophic Accidents are inevitable ~1% of the time**

High Reliability Orgs.

- **Karl Weick and Kathleen Sutcliffe, University of Michigan**
  - **Nuclear Power Plants**
  - **Power Grid Dispatching Centers**
  - **Naval Aircraft Carriers**
  - **Hospital Emergency Departments**
  - **Emergency Medical Teams**
  - **Firefighters**
  - **Air Traffic Control**
  - **Hostage Negotiators**

High Reliability Orgs.

- **Safety is Elusive because it is a "Dynamic Non-Event"**
  - **What produces a safe, stable outcome is constant change**
    - **Continuous mutual adjustment: Respectful Interaction, Communication, Trust, Firsthand Knowledge of the Technology, Attentiveness, Familiarity with each other's roles, experience.**

High Reliability Orgs.

HRO's use 5 Processes to manage:

Anticipation of Failure

- **1. Preoccupation with Failure**
- **2. Reluctance to Simplify Interpretations**
- **3. Sensitivity to Operations**

Containment of Failure

- **4. Commitment to Resilience**
- **5. Deference to Expertise**

High Reliability Orgs.

- **1. Preoccupation with Failure**
  - **Assess all anomalies, mostly small**
    - **Review "quickly", Moments of learning short-lived**
  - **Encourage reporting**
  - **Wary of :**
    - **Liabilities of success**
    - **Complacency**
    - **Temptation to reduce Margins of Safety**
    - **Drift into Automatic Processing**
  - **Train to minimize errors**

High Reliability Orgs.

- **2. Reluctance to Simplify Interpretations**
  - **Encourage Boundary Spanners (with diversity, or you will only see same problems)**
  - **Accept that situation is complex**
  - **Be skeptical of received wisdom**
  - **Always question**
  - **Resist categorization**

High Reliability Orgs.

- **3. Sensitivity to Operations**
  - **HRO's More Situational, Less Strategic** ★
  - **Frequent assessment of Safety Health (Free Lessons – Training, Briefings, Certifications, Hazards Identification, Procedures)**
  - **Reporting:**
    - **If people are not reporting (fear, ignorance, indifference makes no difference) you can't maintain "big picture"**
  - **Ops at the top – Balance Sheets, filtered "good news", Schedule completion**
  - **Ops at bottom – Proper Tool, Component Fit, Schedule Difficulties, Negative Work,…**

High Reliability Orgs.

- **4. Commitment to Resilience**
  - **Not error-free, but keep errors small**
  - **Improvise Workarounds**
    - **Requires Knowledge, Expertise, Training**
  - **Flexible, informal ad hoc groups**
    - **Come together quickly, solve problems, then disband (general uncommitted resources are crucial to resiliency)**
  - **Mentally simulate worst-case conditions (Similar to Fire Drills)**

High Reliability Orgs.

- **5. Deference to Expertise**
  - **Decisions Pushed Down and Around**
    - **Decisions Migrate in Search of Expert**
  - **Situation Dependent:**
    - **Normal Ops – Decisions Come From Top**
    - **High Tempo, Abnormal – Decisions Migrate**
    - **Danger – Predefined Emergency Structure**

(Clear Signals When to Switch)

High Reliability Orgs.

- **Discovering Unknowns**
  - **Combine processes:**
    - **1. Preoccupation with Failure**
    - **2. Reluctance to Simplify Interpretations**

"In the brief interval between surprise and successful normalizing lies one of your few opportunities to discover what you don't know." (Weick and Suttcliffe)

Thought Process

Cognition
Intuition
Inadequacies
Decisions

Relative Advantages

Computer or Mechanical System:

- Fast, Accurate, can solve complex problems
- Can perform mundane tasks,
- Not susceptible to boredom,
- Endurance,
- Multi-tasking,
- Physical power,
- Short and long term memory capability.

Human Brain:

- Superior judgement,
- Can make inferences,
- Can solve problems given incomplete data,
- Flexible,
- Self-programming ability,
- Pattern interpretation,
- Risk-taking capability,
- Ultimately resilient, reliable and safe,
- Use of intuition.

Strengths

- **Cognition**
  - **Deliberate Thinking, Conscious, Neocortex, Prefrontal Lobes, Single Channel Processing, Decision-making, Problem solving techniques**
- **Intuition**
  - **Automatic, Subconscious, Inspiration, Feelings, Creative, “Came to me in a flash”, “Sleep on it”, “Something told me”, “I just knew”**

Human Brain Systems

- Comparison between Neocortex's **Left** and **Right Hemisphere** structure and functions:

Left	Right
Axons: Shorter	Axons: Longer
Similar Neurons	Disparate Neurons
Intensive, detailed	Integrating concepts
Logic	Creativity

Human Brain Systems

- **Comparison between Vertical structure and functions of the brain:**
  - **Neocortex**
    - **Four surface lobes, Data, Cognition, Rationalization**
  - **Limbic System**
    - **Amygdala, Memory, Emotions, Intuition, Values**
  - **Brain Stem**
    - **Mission-critical Functions, Breathing, Heart Beat, Blood Pressure**

Intuition

- **Significance of Intuition**
  - **Intuition is a powerful internal resource and a gift that humans have**
    - **(Retention of knowledge is a skill)**
  - **Intuition is always a response to something**
    - **Everything it communicates to you is meaningful (although it may occasionally send out a signal that is less than urgent)**
  - **Intuition is a cornerstone of personal safety**

Intuition

- **1. Denial of Intuition**
  - **Often, men ridicule the impulse to rely on intuition**
    - **Unless it can be explained logically, some discourage and disregard intuition**
  - **Perception and Intuition are overruled by Judgment**
    - **People are distracted by the way things used to be, could be or should be.**
  - **In an attempt to find an innocent explanation for everything, important information and intuition are disregarded**

Expertise

- **Applying Expertise**
  - The process of editing out of unimportant details in favor of those known to be relevant
  - Many experts lose the creativity and imagination of the less informed
    - Experts are so intimately familiar with known patterns that they may fail to recognize or respect the importance of the new wrinkle
- **Treasured experts**
  - Combine informed opinions with strong respect for their own intuition and curiosity
  - To become expert – Learn
  - To become treasured expert – Unlearn

Human Inadequacies

- **Psychological Reasons for Inadequacies in Human Thought Processes:**
  - **1. Slow, Single Channel Processing (Present)**
  - **2. Desire to Exhibit Competence (Present)**
  - **3. Insufficient Memory (Past)**
  - **4. Omission of Predictive Thought Processes (Future)**

Rules

- **Safety Rules are Unique**
  - **Temptation to Violate**
  - **What happens with Violation?**
    - **Does not usually result in catastrophe**
    - **Positive consequences**
      - **Work made easier**
      - **Reinforces tendency to violate**
    - **Likelihood of disaster increases**
    - **(Post-accident analyses routinely show violations)**

Decisions

- **Cognitive Bias**
  - **The unconscious altering of reasoning used to arrive at conclusions, due to beliefs or assumptions held by a person, which can unintentionally affect the resulting decisions.**

Decisions

- **Decisions made by Individuals**
  - **No single person has enough information or is intelligent enough to make the correct, most effective decisions in large organizations with increasingly complex systems.**
- **Collective Wisdom**
  - **To achieve effective decisions, the leader must enable the collective wisdom of the group.**

Decisions

- To ensure effective decisions, leaders should enable the collective wisdom, by encouraging:
  - 1. Diversity (Individuals and possible solutions)
    - Different data, broader perspective, relevant experience, unique perspective
  - 2. Independence
    - Never compromise integrity
    - Don't change opinions to conform
  - 3. Decentralization (Organization)
    - Allows organization to benefit from the local knowledge of different sub-groups.
  - 4. Aggregation (Collection of inputs)
    - After group members have clearly stated their opinions,
      - "Dissent" can be terminated, and
      - Can be satisfied that they helped the organization make a better, more informed decision

Decision Verification

- **Communication**
  - **After the decision is made, communicate the decision efficiently, with rationale to the organizational groups and individual workers.**
    - **If the leader can't state the rationale clearly enough to convince people, maybe the decision wasn't correct or the most effective.**
    - **If additional information presented, iterate the discussion**

Incorrect Decisions

- **Assessing Decisions**
  - **The assessment of Right or Wrong refers to the decisions, not the individuals**
- **Correcting Decisions**
  - **If a wrong decision is made, the organization's last chance to avert disaster rides on whether it has assembled a support staff or team that isn't afraid to tell the leader that he or she has made a wrong choice or has made a mistake.**

The Next Accident

Columbia, STS-107

- **Columbia Accident Investigation Board:**
  - **"Based on NASA's history of ignoring external recommendations, or making improvements that atrophy with time, the Board has no confidence that the Space Shuttle can be safely operated for more that a few years based solely on renewed post-accident vigilance."**

Challenge

- **How do we stop the next accident?**
  - **"Create foresight – anticipate the changing shape of risk." Deb Grubbe**
    - **Identify new vulnerabilities and paths to failure**
    - **Measure, report, evaluate, and re-analyze the new and existing hazards**
    - **Ask insightful questions**
    - **Use new sensors and filters**
  - **Improve our Safety Culture and Decisions**
    - **Create an Environment that allows reporting w/o fear**
    - **Preserve Values, then Accept Risks**
  - **Eliminate Error-Prone Conditions**
    - **Develop and maintain Situational Awareness**

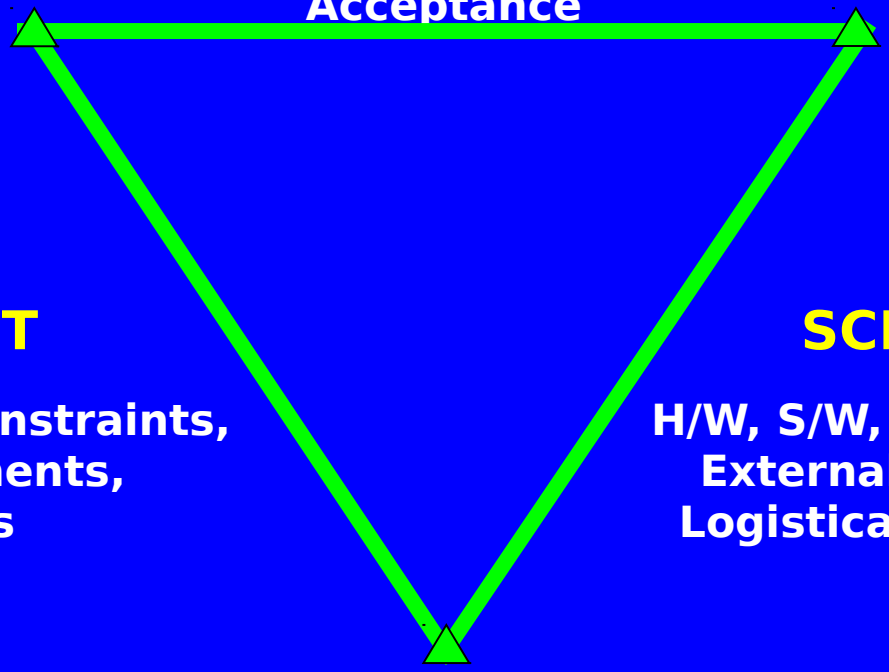
Guidance

- **“Ultimately, we must balance cost, schedule and risk.”**

Program Decisions

TECHNICAL

Performance, Safety, Risk Acceptance



COST

Budgetary Constraints, Improvements, Fixes

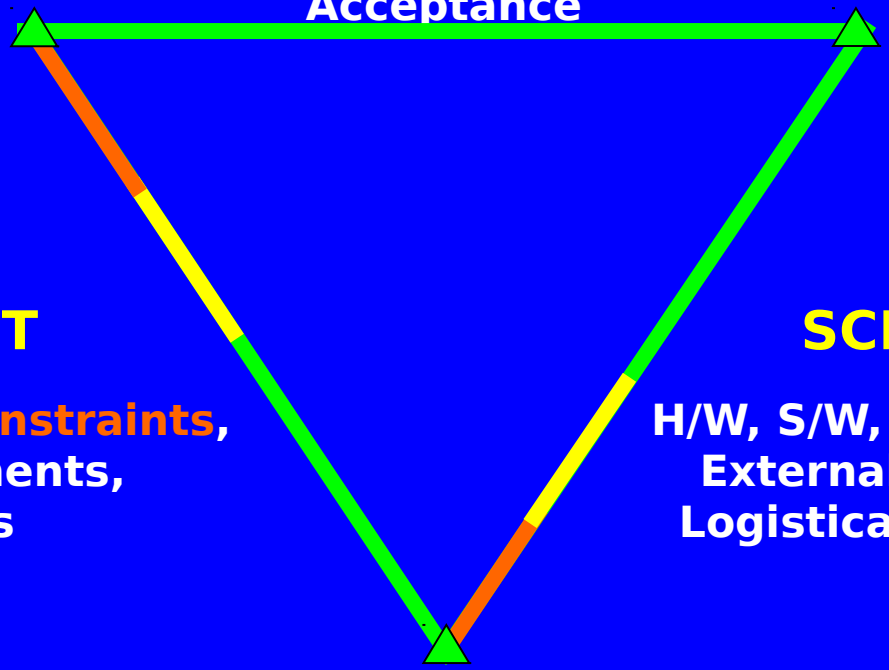
SCHEDULE

H/W, S/W, Personnel, and External Constraints, Logistical Critical Paths

Program Decisions

TECHNICAL

Performance, Safety, Risk Acceptance



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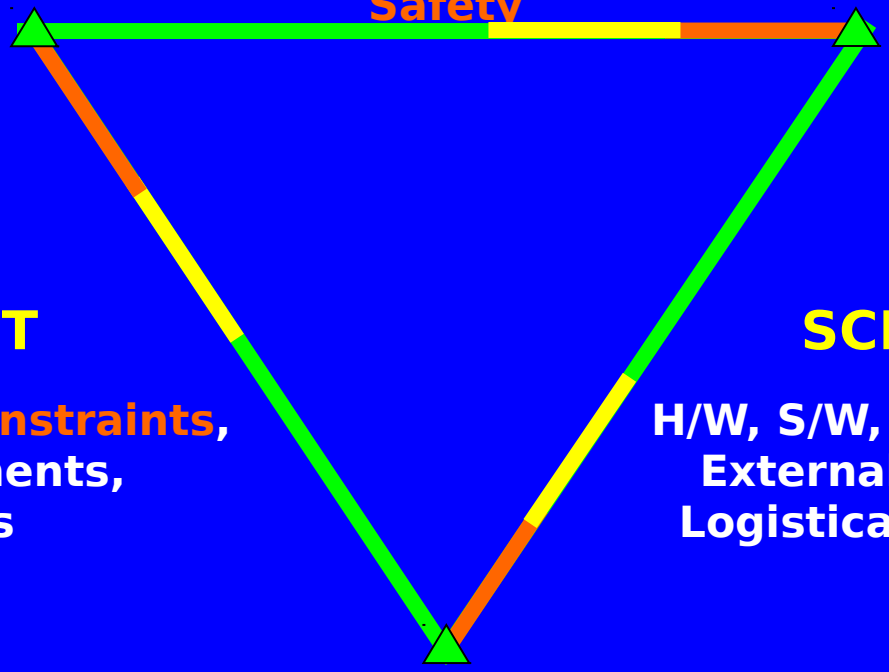
Program Decisions

TECHNICAL

Performance, Safety, Risk Acceptance, Independent Safety



COST

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SCHEDULE

H/W, S/W, Personnel, and External Constraints, Logistical Critical Paths

Cultural Deficiencies

- **Schedule Pressure**
  - Defer Improvements or Fixes (Accept Risks)
  - Won't Search for Vulnerabilities (Ignore Risks)
  - Human Errors Increase (Add Risks)
  - Unsafe Behavior Encouraged (Hide Risks)

- **Technical Inaccuracy**
  - Incomplete Information or
  - Inaccurate Data or
  - Invalid Logic

    → Incorrect Conclusion (Unknown Risks)

Examples

- **"Risky Program" Excuse**
  - **"We can make the Shuttle as safe as possible, and then we'll never fly."**
    - **Sends two messages:**
      - **1. Generic: We're willing to accept additional risk**
      - **2. Specific: We don't want to address your issue**

Risks

- **“Can’t eliminate the dangers associated with hazardous technology (necessary risk), but we must ensure that future technical problems are not compounded by managerial mistakes (accepting unnecessary risk).”**

  – C. F. Larry Heinmann, 1997

Guidance ★

- **“Ultimately, we must balance cost, schedule and risk. When it is time to make this trade, we must have a full and in-depth understanding of the risk.**

– B. Randy Stone, Sept. 2003

Risks

- **Risk Assessment**
  - **Quantitative Accuracy: Difficult or Impossible**
    - **Incomplete data, Complex interaction, Management Risk uncertainties**
  - **Qualitative Estimate: Is Possible**
    - **Must use expertise, judgment, intuition**

Guidance ★

- **"Ultimately, we must balance cost, schedule and risk. When it is time to make this trade, we must have a full and in-depth understanding of the risk.**

  Only then can we apply the best possible human judgment, using proper logic, good rationale, vast experience, high values, and expect the decision to be correct."

Accident signals

- **Every accident gives signals before it becomes an accident**
  - **Anomalies**
  - **Words, data, or charts in meetings**
  - **Weak signals**
  - **Ephemeral signals**
- **Develop senses to detect signals**

Mars Climate Orbiter

- **Spacecraft entered orbit too steeply, crashed on Mars (1999)**
  - **Loss attributed to use of "Metric vs. English Units"**
  - **Problem was observed enroute**
    - **Residual navigation errors were increasing**
    - **More Angular Momentum Desaturation events**
  - **Enroute Navigation group and Entry Guidance group failed to transfer information effectively**

Decisions

- **Information in meetings is often lost or not presented due to:**
  - **“Slidesmanship” (Selling ideas; Biased)**
    - **Power Point, Executive Summary**
  - **Required Systematic Censorship, Patterned Reduction, Simplification**
  - **Lack of Specialization**
  - **Lack of Data**
- **Managers must have <u>all</u> the information necessary to make an informed decision**

Review of Test Data Indicates Conservatism for Tile Penetration

- The existing SOFI on tile test data used to create Crater was reviewed along with STS-87 Southwest Research data
  - Crater overpredicted penetration of tile coating significantly
    - Initial penetration to described by normal velocity
      - Varies with volume/mass of projectile (e.g., 200ft/sec for 3cu. In)
    - Significant energy is required for the softer SOFI particle to penetrate the relatively hard tile coating
      - Test results do show that it is possible at sufficient mass and velocity
    - Conversely, once tile is penetrated SOFI can cause significant damage
      - Minor variations in total energy (above penetration level) can cause significant tile damage
  - Flight condition is significantly outside of test database
    - Volume of ramp is 1920cu in vs 3 cu in for test

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Cultural Environment

- **Reluctance to Voice Dissent, Report Problems, Call "All Stop", "Time Out", Quality "Hex" (Stop Job)**
  - **Administrative / Organizational:**
    - **Fear being fired, Moved, Reduced overtime pay, Comply with orders, See the organization hide problems**
  - **Operational / Production:**
    - **Risk bec. ineffective ("Silver bullets", "Chose battles")**
  - **Emotional / Human Elements:**
    - **Humiliation, Embarrassment, Fear of being wrong, Uncertainty, Intimidating Bosses, Peer pressure, Conform with co-workers, Frustrated with Futility, Room setup, Media influence, Heroic spirit, Competition, High regard for Bosses**

Program Improvements

- **Problem Reporting**
  - **"For NASA workers to speak up, they have to believe that their leaders are really interested in change – and are willing to accept the setbacks that will come when they report problems."**

Tony Ciavarelli, Professor of Applied Psychology, Naval Post Graduate School

Decisions

- **Dissenting Opinions**
  - **Valuable, will protect Organization**
    - **Result in better decisions**
  - **Great Leaders want Dissenting Opinions**
    - **Discourage conformity, encourage dissent**
  - **Dissenting Opinions must be solicited**
    - **People are usually reluctant to voice dissent**
  - **"Mind Guard"**
  - **If absent, group polarization, missing info**

Decisions

- **Open Communication**
  - **Two Advantages**
    - **1. Involve the group's "collective IQ" to achieve better decisions**
    - **2. Quicker acceptance, if dissenters involved in development of rationale and solutions**

Cognitive Complexity

- **Robert Kegan, Harvard Education Professor, 1994**
  - **Five Stages of Cognitive Complexity**
    - **Level 2: "I want my way."**
    - **Level 3: Struggling to find a solution.**
    - **Level 4: Other factors are brought in. Principle values that are larger than we (marriage, love) to help make decision.**
    - **Level 5: She thinks, "I want him to hold his decision, to preserve the tension until a transcendent (beyond limits of experience) solution is realized." It's not about who is right.**

Intimidation

- **Attitude of Leaders**
  - Leaders must exercise vigilance to ensure they are not being perceived as **intimidating**
    - Perceptions are magnified
    - If Leader allows **frustrations** to surface (even if believed justified)
      - Support people will be **intimidated into silence**
      - Bad decisions will likely **not be identified**

Environment

- **Error-Prone Conditions**
  - **Numerous hurdles**
    - **Incorrect Tools, Erroneous Drawings (Engineering Orders), Laborious Paperwork, Demanding Schedules, Training Demands**
  - **Organizational Solution**
    - **Before attempting “behavior-based improvements”, should ask:**

      “How have we failed to help you today?”

Guiding Principles

- **RESPECT – Imagine how great we can become if people of this Agency are respected.**
- **CANDOR – Candor, honesty and truth can only happen if managers create an environment that encourages openness, and they encourage respect.**
- **TRUST – Listen to the experts; after inputs are provided, managers need to trust that the individuals closest to the hardware and data are competent.**
- **MINDFULNESS – Situational Awareness, Emotional Intelligence; Five Processes of High Reliability Organizations.**

NASA Safety Culture

- **Communicate Effectively**
  - Listen, ask the right questions, solicit information
  - Encourage problem reporting, eliminate barriers
  - Encourage dissenting opinions
  - Use Emotional Intelligence to communicate beyond words
  - Use proper meeting management techniques
  - Elevate all concerns that increase risk (to the level of management commensurate with the risk)
  - Understand cognitive biases
  - Learn lessons, use history
  - After decision is reached, communicate down (with rationale), iterate the discussion

Institutional Improvements

- **Organizations**
  - Create resilient organizations, that can absorb failures and human mistakes
    - Centralized Structure – Ensures consistent, unified safety values are promoted by leaders; enables uniform training, ability to correct deficiencies
    - Decentralized Capability – Allows key decisions at all levels; flexibility; best people; can absorb mistakes; defer to experts, even if junior
    - Independent Authority – Independent reporting and funding; more likely to delay a launch and stop an accident

Institutional Improvements

- **Foresight**
  - **Search for vulnerabilities**
    - **Requires knowledge of system, vast experience, intuitive thinking, ability to discern weak signals and identify ambiguous emerging risks**
    - **The system never remains the same – conditions, material, processes, operations change constantly**

Institutional Improvements

- **Values**
  - Make decisions based on **high values**
    - Ask the right questions, receive the correct information, make accurate assessments, then you will be able to live with the decision
- **Rising Standards**
  - Always **learn; continuously improve**
  - **Strive for perfection** – You can't get there, but you must never stop trying

Cultural Enhancements

- **Effective Decisions**
  - **1. Engineering Data (Objective)**
    - **IQ, Education, Engineering, Numbers, Logical Analysis, Rigorous Thinking, Left-Brain**
  - **2. Human Values (Subjective)**
    - **EQ, Emotional Intelligence, Social Skills, Interpersonal Relationships, Intuition, Respect, Inner Voice, Non-Linear Thinking, Right-Brain**

Balance of Opposites

Technical Systems:

- Mechanical
- Closed System
- Linear/Control
- Checklists
- "Bottom Line" Focus
- Plans/Expectations
- Static State
- Metrics/Measurements
- Near Term/Production

Social Systems:

- Human
- Open System
- Relational/Flexible
- Communications
- "Big Picture" Pattern
- Purpose/Values
- Dynamic/Ever-changing
- Face-to-Face Feedback
- Long-

Cultural Enhancements

- **Effective Decisions**
  - **Will yield:**
    - **Fastest,**
    - **Safest,**
    - **Lowest cost possible**

Results (with the most correct balance between Cost, Schedule and Technical)

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